

46.40 Equal mass flow rates of water and a 50/50 glycol-water mixture with specific heat capacity $0.75 \frac{Btu}{lb_m \cdot ^\circ F}$ flow on either side of a shell and tube heat exchanger. Water enters at $90^\circ F$ and the glycol mixture enters at $38^\circ F$. What could be the leaving temperatures of the water and glycol-water mixture, respectively?

- A. $74^\circ F / 50^\circ F$
- B. $74^\circ F / 54^\circ F$
- C. $78^\circ F / 50^\circ F$
- D. $78^\circ F / 54^\circ F$

Assuming 100% efficiency, all the heat extracted from the water is added to the glycol mixture. Equate the heat transfer for the two sides of the heat exchanger. The mass flow rates are the same and thus cancel out. Derive a ratio of the temperature differentials.

$$\dot{Q}_{water} = \dot{Q}_{glycol}$$

$$(\dot{m}c_p\Delta T)_{water} = (\dot{m}c_p\Delta T)_{glycol}$$

$$c_{p,water}\Delta T_{water} = c_{p,glycol}\Delta T_{glycol}$$

$$\frac{\Delta T_{water}}{\Delta T_{glycol}} = \frac{c_{p,glycol}}{c_{p,water}} = \frac{0.75 \frac{Btu}{lb_m \cdot ^\circ F}}{1 \frac{Btu}{lb_m \cdot ^\circ F}} = 0.75$$

$$\Delta T_{water} = 0.75 \times \Delta T_{glycol}$$

To validate this result against intuition, consider that water has a *greater* specific heat capacity than the glycol mixture, and as such, it will have a *smaller* ΔT . Examine the answer choices and note that only one option produces ΔT values in the correct proportion.

$$\Delta T_{water} = 90^\circ F - 78^\circ F = 12^\circ F$$

$$\Delta T_{glycol} = 54^\circ F - 38^\circ F = 16^\circ F$$

These values make the established relation true. Note there are an infinite number of possible solutions, and without multiple choice options being provided, this problem would be underdefined.

Answer D

46.41 A $7lb_m$ cast iron pan ($c_p = 0.1 \frac{Btu}{lb_m \cdot ^\circ F}$) is heated uniformly to $500^\circ F$ during cooking, then placed in a sink filled with 4 gallons of $60^\circ F$ water. Neglecting losses, what is the final equilibrium temperature?

- A. $69^\circ F$
- B. $79^\circ F$
- C. $89^\circ F$
- D. $99^\circ F$

All of the heat released from the pan is added to the water. Express both quantities of heat as the product of mass, specific heat capacity, and ΔT . Set them equal.

$$(mc_p \Delta T)_{iron} = (mc_p \Delta T)_{water}$$

In the case of water, the volume was given instead of the mass. Use the density of water to calculate the mass.

$$m_{water} = \rho V = \left(62.4 \frac{lb_m}{ft^3}\right) \left(\frac{1ft^3}{7.48gal}\right) (4gal) = 33.4lb_m$$

Substitute into the first equation and solve for the final equilibrium temperature, T_f , which is the same for the pan and the water.

$$(7lb_m) \left(0.1 \frac{Btu}{lb_m \cdot ^\circ F}\right) (500^\circ F - T_f) = (33.4lb_m) \left(1 \frac{Btu}{lb_m \cdot ^\circ F}\right) (T_f - 60^\circ F)$$

Since the units are all consistent, it is fine to ignore the units while solving for the unknown temperature.

$$(0.7) (500 - T_f) = (33.4) (T_f - 60)$$

$$350 - 0.7T_f = 33.4T_f - 2002$$

$$2352 = 34.1T_f$$

$$T_f = 69^\circ F$$

Answer A